BY-PRODUCTS FROM GARBAGE

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BY--PRODUCTS FROM GARBAGE

A THESIS

PRESENTED BY

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By-Products from Garbage.

Preface.

The general problem of this thesis is the working out of a method of garbage disposal, without the formation of offensive odors, dust, or fumes, and yet realize a good recovery of valuable by-products.

This problem is a big one for the chemical engineer, and it would take a long time to work out all the details for a new process, so in this work, with the time, material and apparatus available, it was thought advisable to work on only the chemical treatment of garbage, and to merely suggest how it could be handled after this preliminary treatment.

This thesis is presented in three parts: namely, (1) Methods of garbage disposal used today; (2) Experimental work carried out by authors; (3) Suggested method for garbage reduction.

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The writers wish to acknowledge their indebtedness to Prof. H. McCormack for his encouragement and help.

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Part One.

Methods of garbage disposal used today.

By-Products from Garbage.

Introduction.

One of the leading issues in this country today is the demand for economy. Everywhere we are trying to eliminate waste by making use of what was heretofore worthless matter, or matter of little value. Great strides have been taken in many industries along this line; and the work is being actively continued. We all know how common the use of the words "by-product" and "substitute" is becoming. These activities point toward the general trend in this country at the present time.

There are many materials which are worthless in one sense; but which contain certain substances of value. It becomes the duty of the chemical engineer to invent and perfect a method for obtaining the valuable product from the practically useless material which

shall be economical and efficient. Sometimes the very nature of the substances obtained may be altered by the original treatment, consequently the work of this thesis was undertaken to find some way to obtain and use most of the values contained in ordinary garbage, and at the same time dispose of it without the production of disagreeable or offensive odors.

Methods Used for Garbage Disposal Today.

Garbage may be defined for the purposes of this work as rejected food waste, as distinguished from the other waste of a city, such as sewage, debris from the streets, trash, dead animals, etc.

Garbage can be disposed of by the following four methods:- (1) Burying; (2) Feeding to hogs; (3) Incineration; (4) Reduction.

By-Products from Garbage.

It can be seen that when disposed of by the first method all the valuable constituents which it contains are lost. When used as a hog food it is not wasted, but as a rule people object to eating garbage fed hogs. In the incineration method of disposal the green garbage is burnt in specially constructed furnaces, some fuel being added with the garbage to aid in the combustion. Here again most of the by-products are lost, although some heat energy can be recovered, and the cinder which remains can be put to several uses. By using the last of the four methods mentioned for garbage disposal; namely, reduction, an attempt is made to recover or utilize the most valuable by-products contained in the garbage.

Reduction is the leading method of garbage disposal in the United States today. Statistics for the year 1912 show that of the cities of over 30,000 inhabitants having

garbage disposal plants, 28 of these with an aggregate population of over 12 millions, used the reduction process; and 32 with a total population of only 3 million used the incineration method. This alone however, does not indicate the relative advantages of the two processes which can be determined only by a careful comparative study.

Various reduction processes, which differ only in their details, are in use at the present time. The more important of these are:

1. The Cobwell.
2. The Arnold.
3. The Chamberlain.
4. The Merz.

The Cobwell System.

In this system the raw garbage is treated in a container under a pressure of 85 pounds with a liquid such as solvent-naptha. The container is known as the reducer, and is essentially

a closed steam-jacketed kettle with a revolving arm or agitator used for stirring the garbage. This kettle has all the necessary pipe connections and is connected with suitable condensers for liquefying water and gasoline vapors.

At the start of the operation 8-10 tons of garbage are put into the reducer through a charging door. This is then closed and the chamber is flooded with a low grade gasoline or solvent-naptha. Steam is admitted to the outer jacket and the agitator started. The steam enters the jacket at about 60 pounds pressure. The temperature within the reducer is maintained below 200 degrees Fahrenheit. The moisture and gasoline which are volatilized pass off through the vapor-line to a surface condenser. The condensate produced here goes to a settling tank where the gasoline and water are separated by gravity. The water contains little odor and is discharged directly into the sewer.

By-Products from Garbage.

After most of the moisture and gasoline are driven from the garbage the temperature in the reducer rises, thus indicating that the first part of the process, which consists in drying the garbage, is completed. The material is now in a suitable condition for the extraction of the grease. The vapor-line valve is now closed and the material is washed three or four times with gasoline. The mixture of grease and gasoline is pumped from the reducer into a steam-heated still and the gasoline distilled off, the vapors being condensed and piped to storage tanks. When the separation is complete the grease is removed from the still and pumped into suitable tanks or containers.

The material remaining in the reducer is saturated with gasoline which is recovered by opening the vapor line and driving off the gasoline by allowing steam to enter the outer jacket. Most of the gasoline used in this process

can be recovered; the loss being only 1-2 % of the total amount used. The tankage is now dried, ground, and bagged and is ready for use as a fertilizer base.

It is claimed that this process can be used without creating any nuisance due to the escape of odors, fumes, noxious gases, or odorous liquids. The products which result from the above treatment are:

1. Moisture	70-76%	original	weight
2. Grease	2-3 %	"	"
3. Solid material	26-30%	"	"

The tankage obtained contains approximately the following:

Nitrogen	2.7%
Phosphoric Acid	2.0%
Potash	1.9%

By-Products from Garbage.

The Arnold System.

The Arnold system of garbage reduction is used at the present time in Columbus, Ohio. It differs from the Cobwell system in that most of the grease is removed from the garbage before drying it. The raw garbage is charged into a cylindrical container known as the digestor. This is made of sheet steel, lined with cement and tile to protect it from wear due to the agitating of the gritty material when boiling; and also to protect it from corrosion due to the presence of acids in the garbage.

The digestors, when filled, are sealed and steam at a pressure of 60-70 pounds is admitted at the bottom. The top of the digestor is connected by a brass pipe to a condenser. When cooking, the steam is allowed to escape through a 1/4 in. by-pass so as to insure against air binding. The time of cooking varies

with the quality of the garbage, but averages 6 hours.

The cooked garbage is discharged into a receiving hopper directly connected to roller presses. All the apparatus used so far is vapor tight, and all the vapors drawn off pass through scrubbers to remove objectionable odors, these gases may pass from the scrubbers directly into the atmosphere or they may be forced under grates through a bed of fuel.

The liquor extracted at the presses contains most of the grease originally present in the garbage. It is pumped to vertical separating tanks and allowed to stand for some time. Four layers are formed: they consist of, muck; liquor; stilt; and grease. The muck and stilt are drawn off and further pressed, while the grease is drawn off; heated to separate from impurities, and then pumped to storage tanks. The tank water which remains

after the grease is separated is pumped to a large storage tank; it contains 5-7% solid material in solution, and is later evaporated in a triple effect evaporator to a syrupy consistency of sp. gr. 22 degrees Bè.

The tankage from the presses is dried in rotary kilns, and as it contains approximately 10% of the grease originally present in the garbage it is treated in percolators as was the tankage in the Cobwell system. After the extraction the material is saturated with gasoline. In order to recover this and dry the material steam is admitted. The gasoline passes off as a vapor through a vapor line connected with a condenser, where it is condensed and returned to the storage tanks for future use.

The gasoline-grease mixture goes to stills where the gasoline is distilled off, it being condensed as above and pumped to

the storage tanks. The grease is pumped from the stills to the grease storage tanks.

The tankage is discharged from the percolators, and taken by conveyors to the screens where the rubbish and foreign material are removed. This screened tankage is fibrous and readily absorbs the concentrated water from the evaporators, which is added to it at this point. The mixture is then dried and thus all the solids originally contained in the garbage are combined in a dry state. This material is now ready for shipment.

In designing the Columbus plant the first object of the designers was to make it as sanitary and free from objectionable features as possible. Data from the operating sheets for 6 months shows:

Grease from original garbage	2.91%
Tankage " " "	10.0 %
Net profit per ton garbage	$ 1.26

By-Products from Garbage.

The Chamberlain System.

The Chamberlain system differs from the Arnold system just described, in the manner of pressing the cooked garbage. When the digestor is charged a small amount of water is added with the garbage. It is cooked with live steam, but after this preliminary operation is finished the free liquor is pressed out by forcing live steam through the mass from the top and allowing the liquor and steam to pass through a burlap covered strainer which occupies the entire bottom of the digestor. The treatment of the stuff from here on is identical with the Arnold system, no roller presses being used.

The Merz System.

The Merz system of garbage reduction is used in Chicago. The apparatus employed in it is somewhat simpler than that needed in the processes described above.

By-Products from Garbage.

The green-garbage is first crushed to uniform size; this is done to facilitate the drying operation. The drying is carried out in either oil or coal fired rotary kilns.

If the oil is used the drying may be carried out in either one or two stages. If the two stage method is employed the initial drying is done in directly heated kilns and the final drying takes place in indirectly heated ones. In the first kilns the flame comes in direct contact with the material being dried. The wet garbage contains about 70 % moisture and is not charred. The moisture content is reduced to 20 % in the first dryers.

The second set of dryers are heated indirectly, as the material containing a relatively low percentage of moisture would be charred if brought in direct contact with an oil flame. The moisture is reduced from 20 to about 7 % in these second dryers.

By-Products from Garbage.

If coal is used for fuel the drying is carried out in one set of dryers, indirectly heated; the same percentage of moisture being driven from the material as in the case of the oil dryers.

After the garbage is dried it is screened and passed over a magnetic separator, where any iron which may be present is removed; this usually being present in the form of tin cans. The tankage is now conveyed to the percolators, and the grease recovered as in the percolating methods already discribed. Gasoline is used as a solvent and is recovered in the usual manner. After the grease has been extracted, and the excess gasoline driven off by steam, the tankage is put through a dryer and is then finely ground. It is now ready to be mixed with the other ingredients which go with it to make a suitable fertilizer.

By-Products from Garbage.

Part Two.

Experimental Work.

By-Products from Garbage.

The actual experimental work as carried out in the laboratory was as follows:- The garbage to be treated was placed in a copper lined, cast-iron, cylindrical autoclave or digestor. This digestor is 6 inches in diameter, and 12 inches deep. It is provided with a tight fitting iron cover, which can easily be clamped on so as to make the digestor vapor-proof. The cover is provided with a pressure gauge, thermometer well, and safty valve. The digestor has a capacity of 3 liters. It was heated by a gas burner, and all the heat regulation had to be accomplished by regulating the gas supply.

A preliminary safety test on the digestor was made, and a pressure of 150 pounds gauge was obtained without any appreciable leakage, except at the safety valve which started to blow off at a pressure of about 25 pounds; this valve was weighted down during the digestions or "runs" to prevent the loss of vapors.

By-Products from Garbage.

The charge of wet or green garbage was placed in the digestor, and a measured amount of water containing the acids used for disintegrating was then added. A 1000 gram charge with 500 cc. of water and acid was found to be of convenient size for the digestor used. The percentages of sulphuric and hydrofluoric acids used are calculated on the total weight of the charge.

The cover is next placed in position and firmly clamped on; oil and a thermometer are placed in the well; and the gas burner beneath the digestor is lighted. After the temperature reached 100°C., the charge was heated under pressure (except in Run #11) for one hour; the pressure being maintained at its maximum fixed value by regulating the gas flame. The temperature when this working pressure was first reached, and when the heat was removed was recorded. In all cases the latter temperature

was from 5-25 degrees lower than the initial; this drop in temperature was a progressive one, and was evidently due to the formation of vapors more volatile than water through decomposition of the organic material within the digestor.

The digestor and contents were then allowed to cool down to about 50 degrees, when the pressure would be but slightly over atmospheric, before emptying. The cover is now removed and the contents filtered on a Büchner funnel using suction. By this means a dark brown, rather viscous liquor, and a brown to black residue, or "tankage" are obtained. Both usually possess a peculiar odor which, however, was not offensive. In all cases where acid was used to aid in the digestion, the tankage was thoroughly decomposed and after drying was readily reduced to a powder. The fat and grease in the charge were saponified

and gave rise to a layer of fatty acids on the surface of the liquor.

All weighings of charges, liquors, and tankages were made on a pan balance within an accuracy of plus or minus 5 grams. All weights given on data sheets are in grams, temperatures are in degrees Centigrade, and pressures are in pounds per square inch gauge. The thermometer and gauge were assumed to be reading correctly.

A total of eleven runs were made mainly with a vieu to determining the effect upon the digested material when pressure and consequently temperature, and strengths of acid were varied. Table #1 shows the important data on each run and a rough comparison of results. In general it might be said that when ever enough acid was used and the charge heated under pressure the disintegration was fairly complete. The materials obtained were in such a condition

that they could be easily handled. From the results obtained it was determined that from 1-2 % H_2SO_4 and 1/4 % HF in the charge gave the most satisfactory results.

It was the aim throughout these runs to make up the charges as near representative as possible. Such a sample (500 gms.) was analyzed and showed the following composition:-

Water	72.00 %
Nitrogen	.94
PHOSPHORIC acid	.52
Grease (ether extract)	4.32
Ash	3.36

By-Products from Garbage.

Run # 1.

April 2,1917.

Charge:- 1000 gms. garbage
500 gms. water
3% H_2SO_4
1% HF

Log of Run:-	Time	temperature	Pressure
Heat on	9:35	20	
	9:48	100	17.5
	9:58	153	75
Heat off	10:48	134	75

Data and Analyses:-

Weight of liquor	1000gms.
Weight of wet tankage	310gms. (H_2O-65.3%)
Equivalent wt. of dry tank.	108gms.
Nitrogen in dried tankage	2.32 %

Remarks:-

Tankage completely disintegrated; charred considerably by H_2SO_4.

By-Products from Garbage.

Run # 2.

April 2,1917.

Charge:-
1500 gms. garbage
750 gms. water
3% H_2SO_4
1% HF

Log of Run:-	Time	Temperature	Pressure
Heat on	1:23		
	1:50	100	
	2:15	165	100
Heat off	2:50	158	100

Data and Analyses:-

Weight of liquor	1540gms.
Weight of wet tankage	500gms. (H_2O-55.6%)
Equivalent wt. of dry tank.	222gms.
Nitrogen in dried tankage	2.42 %

Remarks:-

Same as Run # 1 in all respects.

By-Products from Garbage.

Run # 3.

April 3, 1917.

Charge:-	
	1000 gms. garbage
	500 gms. water
	2% H_2SO_4
	1/4% HF

Log of Run:-	Time	Temperature	Pressure
Heat on	9:06		
	9:27	100	15
	9:38	163	100
Heat off	10:27	157	100

Data and Analyses:-

Weight of liquor	800gms.
Weight of wet tankage	510gms. (H_2O-50.9%)
Equivalent wt. of tank.	250gms.

Composition of dry tankage:-

Nitrogen	2.29 %
Phosphoric acid	4.88
Ash	28.08

By-Products from Garbage.

Run # 4.

April 3, 1917.

Charge:- 1000 gms. garbage
500 gms. water
1 % H_2SO_4
1/4 % HF

Log of Run:-	Time	Temperature	Pressure
Heat on	1:50		
	2:00	100	40
	2:10	156	100
Heat off	3:00	139	100

Data and Analyses:-

Weight of liquor	845gms.
Weight of wet tankage	490gms. (H_2O-44.2%)
Equivalent wt. of dry tank.	265gms.
Nitrogen in dried tankage	3.18 %

Remarks:-

The best run; tankage was black, possessed only a slight odor and was thoroughly disintegrated; good separation of fatty material and liquor.

By-Products from Garbage.

Run # 5.

April 4, 1917.

Charge:- 1000 gms. chopped garbage

500 gms. water

0 % H_2SO_4

0 % HF

Log of Run:-	Time	Temperature	Pressure
Heat on	1:05		
	1:12	100	15
	1:25	159	100
Heat off	2:12	153	100

Remarks:-

No results as material was discarded due to offensive odor and incomplete decomposition.

By-Products from Garbage.

Run # 6.

April 9, 1917.

Charge:- 1000 gms. garbage
500 gms. water
2 % H_2SO_4
0 % HF

Log of Run:-	Time	Temperature	Pressure
Heat on	10:06		
	10:20	100	20
	10:30	155	100
Heat off	11:20	131	100

Data and Analyses:-

Weight of liquor	1200gms.
Weight of wet tankage	320gms. (H_2O-61.0%)
Equivalent wt. of dry tank.	125gms.
Nitrogen in dried tankage	3.38 %

By-Products from Garbage.

Run # 7.

April 9, 1917.

Charge:- 1000 gms. garbage

500 gms. water

0 % H_2SO_4

2 % HF

Log of Run:-	Time	Temperature	Pressure
Heat on	1:50		
	2:00	100	10
	2:08	165	100
Heat off	3:00	160	100

Data and Analyses:-

Weight of liquor	1000gms.
Weight of wet tankage	400gms. (H_2O-54.8%)
Equivalent wt. of dry tank.	180gms.
Nitrogen in dried tankage	3.13 %

By-Products from Garbage.

Run # 8.

April 12, 1917.

Charge:- 1000 gms. garbage
500 gms. water
2 % H_2SO_4
1/4 % HF

Log of Run:-	Time	Temperature	Pressure
Heat on	9:07		
	9:12	100	
	9:20	165	100
Heat off	10:12	145	100

Data and Analyses:-

Weight of liquor	750gms.
Weight of wet tankage	550gms. (H_2O-60.2%)
Equivalent wt. of dry tank.	219gms.
Nitrogen in dried tankage	3.77 %
Phosphoric acid " "	2.95 %
Ash " "	30.03 %

Remarks:- Little separation of fatty material; rather foul odor.

By-Products from Garbage.

Run # 9.

April 12, 1917.

Charge:- 500 gms. garbage
250 gms. water
2 % H_2SO_4
1/4 % HF

Log of Run:-	Time	Temperature	Pressure
Heat on	2:05		
	2:09	100	
	2:14	165	100
Heat off	3:09	153	100

Data and Analyses:-

Weight of liquor	470gms.
Weight of wet liquor	230gms. (H_2O-55.2%)
Equivalent wt. of dry tank.	103gms.
Nitrogen in dried tankage	3.43 %

Remarks:-

Little or no fatty material; odor not objectionable.

By-Products from Garbage.

Run # 10.

April 13, 1917.

Charge:- 1000 gms. garbage
500 gms. water
2 % H_2SO_4
1/4 % HF

Log of Run:-	Time	Temperature	Pressure
Heat on	2:18		
	2:22	100	30
	2:30	160	100
Heat off	3:22	133	100

Data and Analyses:-

Weight of liquor	940gms.
Weight of wet tankage	460gms. (H_2O-59.5%)
Equivalent wt. of dry tank.	186gms.
Nitrogen in dried tankage	2.29 %

By-Products from Garbage.

Run # 11.

April 16, 1917.

Charge;- 1000 gms. garbage
700 gms. water
2 % H_2SO_4
1/4 % HF

Log of Run:-	Time	Temperature	Pressure
Heat on	9:30		
	9:40	98	-------
Heat off	10:30	98	-------

Remarks:-

This charge was heated in the open digestor. The odors given off during cooking were objectionable. After cooking one hour the material obtained was discarded without further treatment. The tankage was brown in color and only partially decomposed; a bone in the charge was apparently unaffected.

By-Products from Garbage.

Table No. 1.

Run	Garbage grams	Water grams	H_2SO_4 %	HF %	Pressure pounds	Temperature maximum
1	1000	500	3	1	75	153
2	1500	750	3	1	100	165
3	1000	500	2	½	100	163
4	1000	500	1	¼	100	156
5	1000	650	-	-	100	159
6	1000	500	2	-	100	155
7	1000	500	-	2	100	165
8	1000	500	2	¼	100	165
9	500	250	2	¼	100	165
10	1000	500	2	¼	100	160
11	1000	700	2	¼	-	98

Time of digestion in all runs was one hour after temperature reached 100 degrees. Original garbage assumed of one average composition of 70% Moisture and 30% dry tankage.

By-Products from Garbage.

Table No. 2.

Run	Wet tankage grams	Dry tankage grams	Liquor grams	Remarks
1	310	108	1000	Completely disintegrated.
2	500	222	1540	Same as Run 1.
3	510	250	800	Disintegrated
4	490	265	845	Large amt. fatty material. Good run.
5	---	---	---	Tankage and liquid discarded
6	320	125	1200	Disintegrated
7	400	180	1000	"
8	550	219	750	"
9	230	103	470	"
10	460	186	970	"
11	---	---	---	Partially decomposed.

By-Products from Garbage.

Analyses of original garbage, tankages, and liquors.

Original Garbage.

A 500 gram sample of garbage, representative of the material used in the runs, was placed on an enammeled pan and dried in a steam-heated drying oven at a temperature of 85-95 degrees for 12 hours. When cool the dry residue was weighed, and the loss in weight (71%) was considered as moisture. This dry residue was then ground in a coffee mill and the whole sample was made to pass through a 10-mesh sieve. The material obtained was a brown, somewhat greasy substance resembling coffee-grounds in appearance. It possessed little odor.

A 5 gram sample of the ground, dried material was further dried at 100-120 degrees for 5 hours and was found to contain .84 % moisture. Therefore, the total moisture content of the original garbage was about 72%. This

thoroughly dried sample was used in the following analyses.

A 1 gram sample of the above material was ignited to constant weight in an electric oven for 1 1/2 to 2 hours, and the residue was considered as ash.

Nitrogen was determined on a 1 gram sample of the dried material by the Kjeldahl-Gunning method, using 25 cc. conc. H_2SO_4, .75 gm. HgO, and 10 gms. K_2SO_4, for digesting. $KMnO_4$ was not added after the digestion was completed. The material was digested for an hour after the solution became colorless. Paraffin was added to the cold diluted solution in the Kjeldahl flask to reduce foaming, granulated zinc was also added to prevent " bumping " during the subsequent distillation. 25 cc. of 4 % K_2S was added to precipitate the mercury present. An excess of the cold conc. solution of NaOH was

added from a dropping funnel in the stopper of the flask, and the ammonia liberated was then distilled into a beaker which contained 50-75 cc. of approximately tenth-normal HCl. Methyl orange was used as an indicator in the subsequent titration to determine the amount of ammonia liberated.

Phosphoric acid (P_2O_5) was determined by weighing the dried yellow-precipitate of ammonium phosphomolybdate of which .0374 is P_2O_5. In this determination a 1 gram sample was first decomposed with nitric and hydrochloric acids. After evaporating to dryness the residue was taken up in concentrated nitric acid and the organic matter oxidized with chromic acid and ammonium persulphate. The phosphorus was precipitated with ammonium molybdate.

A 5 gram sample was extracted with ether for 8 hours in a Soxhlet tube to determine the

amount of grease present.

The following is a tabulation of the results obtained on the raw garbage.

Wet Basis.

Moisture...........	72.00 %
Nitrogen...........	.94
Phosphoric acid....	1.05
Ether extract......	4.32
Ash................	3.36

Dry Basis.

Nitrogen...........	3.36
Phosphoric acid....	3.76
Ether extract......	15.44
Ash................	12.00

Analysis of tankages.

Moisture was determined on all tankages by drying a 5 gram sample for 8-10 hours at 100-120 degrees. These dry samples were then used in making the other analyses. All tankages were analyzed for nitrogen by the same method described under

nitrogen determination in original garbage on a 1 or 2 gram sample. The material was colorless after digestion for 1 to 1 1/2 hours. Tankages from runs # 3 and # 8 were analyzed for phosphoric acid and ash.

Analysis of Liquors.

Liquors from runs # 3 and # 8 were analyzed for nitrogen and phosphoric acid. Liquors from runs # 8,3, and 10 were analyzed for dry residue (above 120 degrees), and ash, while the glucose content from run # 10 was determined by Fehling's method.

The results obtained in all analyses are summarized in the following table.

By-Products from Garbage.

Table No. 3.

Analyses made on original garbage and tankages.

		Dry basis.		
Sample	Moisture %	Nitrogen %	Phosphoric acid %	Ash %
0	72.0	3.36	3.76	12.00
1T	65.3	2.32		
2T	55.6	2.42		
3T	50.9	2.29	4.80	28.08
4T	44.1	3.18		
6T	61.0	3.38		
7T	54.8	3.13		
8T	60.2	3.77	2.95	30.02
9T	55.2	3.43		
10T	59.5	2.29		

0= Original Sample

1T= Run # 1 tankage. Etc.

By-Products from Garbage.

Table No. 4.

Analyses made on liquors.

Sample	Residue above 120 %	Nitrogen %	Phosphoric acid %	Ash %
3	15.52	.585	.383	2.33
8	10.89	.532	.340	1.51
10	9.42			1.51

Glucose in # 10 = .58%

Additional data and experimental work.

An attempt was made to purify the fatty material formed during the digestion of the original material, by steam distillation, distillation under reduced pressure, and extraction with ether and alcohol.

In attempting to distill under reduced pressure a temperature of 225 degrees was attained, when a mass of charred material; and a heavy,

fairly clean grease remained. The charring was evidently due in part to impurities present. The alcohol and ether did not appear to dissolve any of the material. Heating the mixture with bone charcoal did not remove much color or impurities.

An attempt was made to generate alcohol from the glucose in the liquors of runs # 1 and # 4. The liquors were neutralized and clarified through the addition of lime and ferrous sulphate and then filtered hot to remove albuminoid matter. The resulting filtrate was cooled to 15-20 degrees and ordinary bread yeast added. After allowing the yeast to act 72 hours the liquor was distilled, but no alcohol was formed as the first drop distilled over at 98 degrees.

By-Products from Garbage.

Part Three.

Suggested method for garbage reduction.

By-Products from Garbage.

The successful operation of a commercial process depends largely on the value of the materials obtained. The following figures are supplied to give some idea as to the valuable constituents in a ton of green garbage.

The following prices per pound for plant food fertilizer material, based on the average wholesale prices of the materials, for a period of 6 months, beginning Sept. 1, 1914 was adoped by the Eastern Agricultural Experiment Station.

Nitrogen............	$ .20
Phosphoric acid.....	$ .04
Potash..............	$ .085

The garbage sample analyzed by us contained the following percentages of fertilizer materials:

Nitrogen.............	.94%
Phosphoric acid......	1.05
Potash.(K_2O)........	1.00

Here the percentage of potash is assumed to be about the same as that of phosphoric acid. One ton of the raw material would have the following value as a fertilizer:

Nitrogen...............	$3.76
Phosphoric acid........	$ .84
Potash.................	$1.75
	$6.35

Further, assuming the value of the grease to be $.05 per pound, a ton of garbage, containing 4.30% grease, has an additional value of $ 4.30. Therefore the lowest value of the products in one ton of garbage is $ 10.65.

The by-products obtained through a new process should net at least the amount obtainable through the use of an older process, other things remaining constant. With this in vieu the following process is recommended by the authors.

By-Products from Garbage.

In the first place the garbage is digested and disintegrated under a pressure of 100 pounds, in the presence of 2 % H_2SO_4 and 1/4% HF. This could be carried out in a large (10-15 ton) cast-iron, lead-lined digestor. Heat is supplied by means of open and closed steam coils within the digestor. These coils would have to be protected by a lead sheathing. The working steam pressure would be 120 pounds. Agitation is assisted by a mechanical stirring device.

The digestor is charged through an opening at the top, and the cooked material withdrawn at the bottom. The material is held at the maximum pressure for 45 minutes, and is discharged, when cooled to 50 degrees, directly onto the roller presses. Here most of the liquor is separated from the tankage.

The liquid goes to the separating tanks where the layer of fatty acids is recovered.

Cast-iron apparatus could be used with this material as the acid is not strong enough to affect it seriously. After the grease has been separated the liquid may be concentrated to "stick" and added to the tankage at the proper time.

The tankage from the presses is dried, (the stick could be added before it is dried), and ground and is ready for use as a fertilizer material.

The advantages of the above process are: first, it saves time; second, after the cooking no vapor tight apparatus is needed; third, no condensing towers used; fourth, materials obtained are in better condition to handle than in other processes; fifth, large tonnages could be handled in a small area.

In the process of the nature outlined at the beginning of the thesis, the

time of cooking was about 6 hours. In most of them vapor tight apparatus and condensing towers were used. The fact that a digestor charge can be treated in a short time shows that fewer digestors would be necessary to handle a given tonnage, and thus space and capital would be saved.

It is hoped that this work shows the practicability of treating garbage in the manner outlined.